CURSORY REMARKS

ON

WHEEL CARRIAGES.

PART II.

BY

JOHN COOK,

OF LIQUORPOND STREET,

YOUNGER SON OF THE LATE MR. WM. COOK, COACH BUILDER, OF THE ABOVE PLACE.

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PREFACE.

HAVING made a promise in my "Cursory Remarks on Wheel Carriages," to furnish the public with a more ample illustration of wheels, together with correct drawings of, and explanations on, every principle of carriage in use, it becomes necessary for me to apologize for these drawings, and remarks, not appearing with this small publication, and to observe, that, from some peculiar circumstances involving my best interests and future welfare, that at no distant period will be made public, I am under the necessity of suspending for a time that part of my promised publication. I therefore beg leave for the present to claim this indulgence. But feeling that I might with propriety withdraw from it those remarks which bore more immediately upon the subject of wheels, and which was intended to be embodied with that work; and that, while it would not injure my prospects, it would form a very appropriate second part to my "Cursory Remarks." I have therefore ventured to publish it as such, leaving the whole to the candid consideration of

those who choose to honour it by a perusal. I have also to observe, that my experiments have been more confined than I intended; but as general principle, more than perfect accuracy, has been my aim, in order to give some sort of criterion founded upon scientific principles, for their general application, I trust they will be found to have answered my purpose. To many gentlemen and others who are partial to mechanical research, and to all concerned in the use of wheels, the following remarks, I am induced to think, will not be either uninteresting or useless; and as I throw them on an enlightened and impartial public, I shall rest satisfied, by leaving them to their fate.

And am, with much respect,

The Public's obedient servant,

THE AUTHOR.

9, Fitzroy Place, Kentish Town.

REMARKS

ON

WHEEL CARRIAGES.

IN treating of the subject of the comparative advantages of high and low wheels, on which so much contrariety of opinion has been expressed, it is, I consider, next to impossible, in order to come to any fair conclusions, to unconnect it with the roads on which they have to travel.

The excessive draught, and consequent fatigue to the horses from travelling on soft roads, is evident to the driver of every vehicle, and is at once a proof of the above assertion. In the dry summer season, those parts of the road which have been recently watered, are discovered by coachmen to add immediately to the draught the instant they drive the carriage upon it, and is sure to call down from them an opprobrious epithet upon the promoters of that act. As at least two-thirds of our seasons are wet, we ought to provide as much as possible a remedy for the inconvenience they occasion in this respect; for it does not require any ingenuity to discover that this difference of draught spoken of, must arise from the sinking of the wheel, thereby in effect lessening its circumference, and forming, as it were, a hill. Our forefathers were so sensible of this fact, that by a legislative enactment, they have allowed waggons to carry half a

ton more in the summer than in winter; and common sense will inform us, that a small wheel will sink deeper into soft ground than a large one; and will therefore, from this circumstance alone, suggest the exclusion of the former, and the adoption of the latter. Then when we consider how much friction is overcome by the increased size of the wheel, and the increase of power given to the inertia of the carriage, particularly on level roads by the lengthened lever, (which inertia, I shall shortly have occasion more particularly to explain) I think the mind must be induced to assent to their preference and adoption. Besides these considerations, there are others not less important, which involves both the comfort and expense of the proprietors of carriages; viz. their contributing in an eminent degree to lessen that disagreeable noise which is generally heard inside, by their passing over uneven surfaces with a superiority of ease, that is manifest to almost every person, who but for a moment contemplates the subject.

The consequence of this circumstance must be equally obvious, viz. that they convey less jar to the carriage, and therefore it must of necessity, and I well know from experience, does wear considerably longer; for there can be no doubt that it is this tremendous jar or tremor conveyed to carriages and their wheels, by their passing over these uneven surfaces, separating both the closeness of the frame-work, and the component parts of the timber itself, by destroying the natural cohesion between the particles, that wears them out in so short a time: As we always find that carriages used on London stones do not wear above 1-3d so long as in the country. To this cause we may attribute the decaying and giving way of the beds of the axis, and those parts adjacent, which we generally find are the first to fail, and why the whole carriage decays sooner than the body, which is generally on springs.

There are some persons who assert that the small wheel is stronger than the large one, an idea which no doubt is derived from considering small arcs as capable of sustaining greater burden than large ones. This idea, abstractedly considered, is very just, but will not apply to the wheel of a carriage; for wheels being made of materials which jar on percussion, materially deteriorates, and having constantly to pass over uneven surfaces, which engender that jar, or series of percussions, the more we reduce the wheel to the size of such uneven surfaces, the greater power of resistance will such surfaces have over the wheel. Experience fully establishes this fact, and falsifies the above assertion; for the fore-wheels of carriages are always without exception worn out first, the joints more shaken, and the iron thinner than the hinder ones; this being uniformly the case, I hope no one will contend that wheels lose their strength from being high, otherwise the hind wheels would uniformly be worn out first, which every coachmaker and hackneyman knows is contrary to experience. In fact, the higher wheels are, the more capable are they to withstand the shocks of their resisting medium, which are in effect thereby rendered weaker.

It appears evident, I trust, from the foregoing practical information, that wheels are not less strong from being high; but in order to prove more decisively the relative utility and superiority of high wheels, I shall endeavour to dip somewhat deeper into the inquiry, and shall strive to rescue this subject from the uncertainty in which it seems to be involved. Indeed I cannot help observing, that I have considered it almost a disgrace to the enlightened state of mechanical knowledge, that the subject of carriage wheels is still the theme of hypothesis, and that no fixed or certain principles have been laid down for their use. If, therefore, I fail in the attempt, it will only add one more to the unavailing endeavours which have been before the

public; but on the contrary, should it throw but a small degree of light upon the subject, it will not, I trust, be wholly useless, inasmuch as it may form at least a stimulus to the further exertions of others.

In prosecuting this short inquiry, it appears to me there are five points or considerations indefeasibly connected with it, and which must not be lost sight of during our progress: viz. 1st, the inclined plane. 2dly, the relative weight of wheels to their burden. 3dly, the vis inertia of the carriage. 4thly, the state of the roads; and 5thly, friction between the axil and box.

The inclined plane is extremely important in this consideration, and I may say forms the test of our research; and from which I trust I shall be enabled to deduce some important phenomena, that I believe has hitherto escaped observation.

The next point, viz. the relative weight of wheels to their burden, is not less important; and I consider that they should not be treated of as apart from, but always as attached to, a carriage.

The vis inertia likewise is a constant companion of the whole, and must be brought in for its full share of the powerful effects produced.

The state of the roads, as being continually variable, at all times consequently affecting the progress of the vehicle, cannot be left out of the question, and the well known accompaniment. Friction must on no consideration be disregarded, being one of the greatest drawbacks to the progress of a carriage we have to contend against.

As we find hills add so excessively to the draught, and that in proportion to steepness of the ascent, and as this situation is the worst that horses have to contend against, I consider that it is a most important thing to ascertain, in adapting wheels to carriages, their effect and relation, and what are the steepest hills horses have to encounter with them. For the steeper the hill the greater will be the power required to draw any burden up such hill; and the

Plate. 1.

Fig. 1.

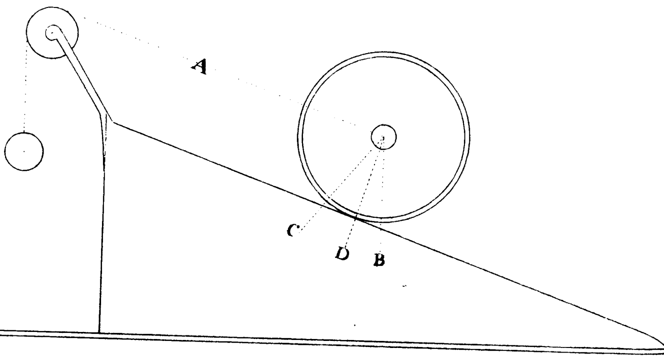
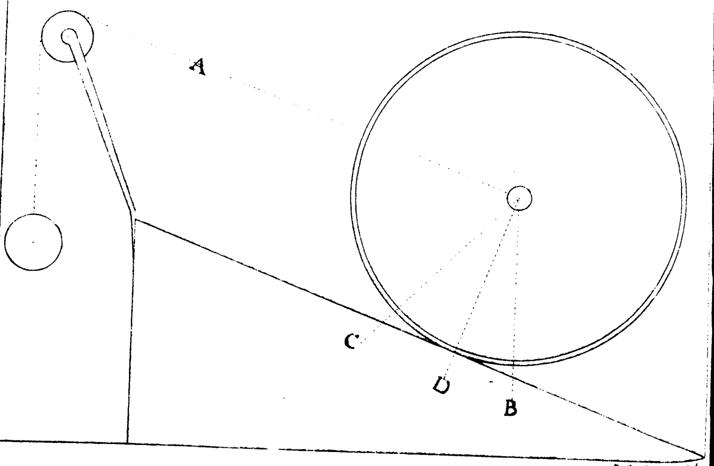


Fig. 2.



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heavier the weight is, so in proportion must the power be increased.

A wheel, therefore, which is six feet high being as heavy again as one of three feet, that is, supposing them to be of equal strength, must of necessity require a greater power to purchase the weight. See fig. 1 and 2. pl. 1.

In examining these figures, it must naturally occur to us on the first inspection, that the power which holds fig. 1 in equilibro will not be sufficient to hold fig. 2 in equilibrio, the latter being as high again, and therefore of twice the weight.

In applying the observation on wheels descending inclined planes, in my "Cursory Remarks," page 12 and 13, to the opposite situation, we shall be led to conceive, without close examination, that as in that situation the weight in the higher wheel, from being elevated, and consequently overhanging the fulcrum of the wheel further in proportion to its height, and thereby pressing with a corresponding force; so in this opposite situation, the weight overhanging the fulcrum of the large wheel further than the small one, will therefore, from that circumstance, give an equal resistance. But this is not the case; for in the first instance the effect stated has merely a reference to the wheel and its fulcrum on the ground, producing a greater degree of power as regarding the wheels' velocity. While in the latter instance it has reference only to the weight itself which acts upon the wheel; for with respect to that weight, which is to be considered as the burden, situated upon an inclined plane, whether it be placed upon high or low props, its relative gravity is precisely the same, that is, with regard to the effect it may have in the line of traction. In the latter case the effect of the weight in the centre of the wheel becomes altered by being acted upon by a power in the direction of the line of draught A, while its natural tendency is pressing in the direction of the line B, so that it may be said to

take a medium or diagonal course, like a ship acted on by the water and the wind, and therefore takes the direction of the line C.

We perceive also, the weight in going up hill must be taken by the horse in the direction of A, and therefore loses its power of acting with its whole force in the line B ; for until the effect of the weight be removed so far forward as to pass the line D, the whole carriage will remain motionless. But it will be useless to consider the subject of wheels as they may appear sketched upon paper, we must recollect their actual weight, and that any addition of height is attended with a proportional increase of weight, which I shall have occasion to consider more particularly, as being an essential feature in enabling me to ascertain where to limit their height, which, notwithstanding such increase of weight, may be carried to considerable excess before any disadvantage will be experienced.

I propose to make a few observations on the five foregoing points, in a somewhat retrograde order. I shall begin with that of inertia, which, as I have observed, I consider to be indefeasibly connected with this whole subject, and which would therefore be greatly wanting and highly defective without it.

Inertia, or vis inertia, is described by Sir Isaac Newton to be "a power implanted in all matter whereby it resists any change endeavoured to be made in its state," or, "a principle by which bodies persist in a state of motion or rest." I may here observe, it is to this principle we owe the regular motion of our own bodies in walking, that of birds in the air, and indeed of all animals as well as of machines, and which prevents us and them from being forced along by juts or throws, which, without this peculiar property of matter, must have been the case. For the purpose of explaining the effect of this principle on carriages, I shall consider inertia to be divided into two sorts, viz. active inertia and passive

inertia; the first as regards the body being in motion, the latter as it regards its being at rest.

These two states, when considered with respect to carriages, have very different effects; and in our experiments on this subject of draught-wheels, &c. unless we pay due regard to the effect this universal and inherent property of matter has upon them, our conclusions will be erroneous.

The carriage itself, when considered in reference to this principle, must also be treated of as divided into two parts, viz. the carriage and its wheels, which are affected somewhat differently, and which will require rather a distinct inquiry.

The active inertia peculiar to a carriage may be easily perceived when, being drawn along at a brisk pace, the horses are required suddenly to stop its progress. At this moment they are obliged to exert their utmost strength, in a contrary direction, to effect the object. When a carriage is going at the ordinary rate, if the horses could be released at the same instant, we should find the carriage go forward of its own accord several yards beyond the place where the horses were released.

The quantity of inertia in a carriage depends upon three circumstances, viz. the quantity of power applied, the height of the wheel, the friction within the box of the wheel (the measure of which at all times depends upon the quantum of superincumbent weight), and the state of the roads. In proportion to the hardness and smoothness of the boxes and axles, the height of wheel, and the hardness of the road, so much will the inertia be facilitated, and their resistance overcome.

This principle of active inertia is of the highest importance in the draught of a carriage; and the great secret of easy draught lies in constructing the carriage, so as this inertia of its whole weight may, with the application of springs, act upon the axles of the wheels as one condensed mass of matter.

The passive inertia of the carriage may be strongly

evidenced by the following circumstance, viz. when horses attempt to start with a carriage at rest, they are obliged to exert a considerable deal more power than is afterwards required to keep up the motion. As the weight in the first case endeavours to preserve its state of rest by its unwillingness to be moved, so in the latter case, when in motion, it endeavours to preserve or persevere in that state likewise.

The inertia of a carriage in motion is liable to be counteracted by several adventitious circumstances, such as the sinking of the wheels in soft roads, inequalities, as stones, gravel, a strong current of air, &c.; and the friction in the boxes, which, in hoged roads*, as they are termed, is greatly augmented, matters to which I shall have occasion again to allude. Independently of this inertia of the carriage itself, the wheels have likewise an inertia of their own, which in point of velocity is generally as that of the carriage increasing or diminishing exactly in proportion as its velocity becomes more or less.

I shall now therefore inquire more particularly into the general effect of this inertia in regard to wheels, which are immediately opposed to, and effected by, the impediments of the road, and the excessive friction in their centres from the superincumbent weight. If we observe a boy trundling a hoop, we may notice what a regular motion it has, although the impulses are communicated by successive strokes, and if it were not of this peculiar property, would go forward by throws and starts, as before observed. So again in the balance of a watch, a pendulum, and numerous other instances. Now, if we contemplate the relative motion of a large and of a small wheel, we must consider both of them as attached to a carriage, and therefore put

* Roads elevated in the middle, the effects of which, on the Hastings road, there fell most severely upon a passenger of the Swan coach, and also upon its proprietor, in a late trial at Guildford.

Plate. 2.

Fig. 1.

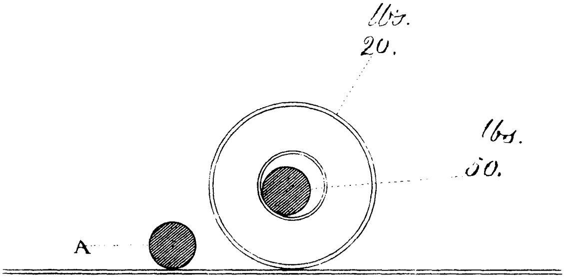
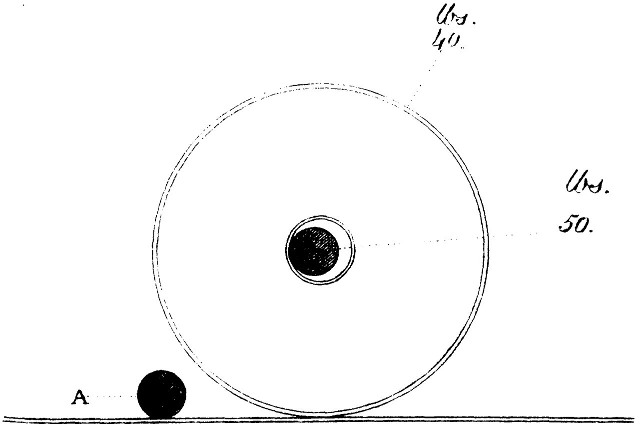


Fig. 2.



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into action by the same power or weight, and that power constantly acting upon them in their progress over the same impediments or roads; this will naturally lead us to the observations following:—

Suppose two wheels in motion, one of them as high again as the other (see plate II. fig. 1 and 2.) and having to pass over the same sized obstacle A.

Now, as both of these wheels are to be considered to be put in motion by the same force, and that force or weight (say fifty pounds) accompanies them during the whole time of the revolution, which is an important circumstance to be considered, they must each acquire the same velocity; and from which we must infer, that both wheels would gradually acquire the precise velocity of their accompanying impulse (for I before remarked, a carriage wheel can have no acceleration beyond that of the carriage, as that at all times governs the wheels); as this is the case, we conclude, that notwithstanding the weight of the large wheel is double that of the small one, it must actually acquire the velocity of the latter. If so, then the first principle of mechanics will inform us, that if a body of a given weight has a velocity equal to another body of half that weight, it must overcome or strike against a third body with double the force, because here a double weight is assimilated into the same velocity. Therefore the obstacle A (even if the wheels were of equal height) would be overcome with twice the ease; and, multiplying the velocity into the weight of each gives us their power.

As suppose the high wheel to weigh	40 lbs.
and the velocity	20
multiplied together, gives	800
And suppose the lower one to weigh	20 lbs.
and its velocity the same or . . .	20
multiplied, gives	400, half the

force of the former.

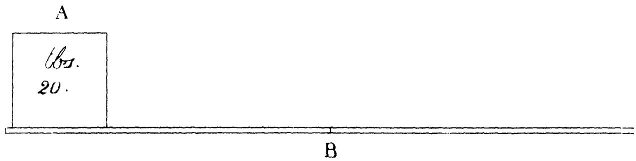
But as this double weight arises from a double height, and as that height, we find by experiment, gives, even from a state of rest, nearly a proportionate advantage, I trust it must be acknowledged highly superior.

It is owing to this active inertia of matter, before referred to, that the increased weight of high wheels becomes of no material disadvantage; and when, I say again, we consider that this increase of weight is the consequence of an increase of height, we shall become the more sensible of their superiority. Let us examine farther:—

Suppose the wheel (see fig. 1 and 2) to be as high again as the other, and impelled with an equal degree of force along the same road, and pressed by the same superincumbent weight, we shall find, that as the line of inertia, formed as in "Cursory Remarks," p. 10, is thrown as forward again on the ground as that of the small one, so will it pass over the inequalities or obstacles with twice the ease; and therefore these obstacles cannot retard the velocity of the high wheel as they would the small one: and when we add the extra weight of the high wheel, which is assimilated into the velocity to the advantage of its lever-like principle from its height, its superiority in this light, and in every point of view on level road, I submit, must appear greatly in favour of its adoption. We may add to these considerations, that it is the softness of the roads that occasions a greater draught to the carriage than any other circumstance, from its allowing the superincumbent weight to press them into it, thereby weakening the force of the inertia of the wheels themselves, and therefore we may conclude, that the inertia or force of the carriage, which gives motion to the wheels, must likewise be lessened, and so retards the velocity of the whole machine, by weakening the momentum of the source of their motion, and hence the increase of draught. As, therefore, we find that high wheels to a burden require less power than small ones to pull them

Plate

Fig. 1.



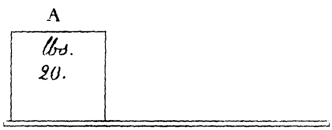


Fig. 2.

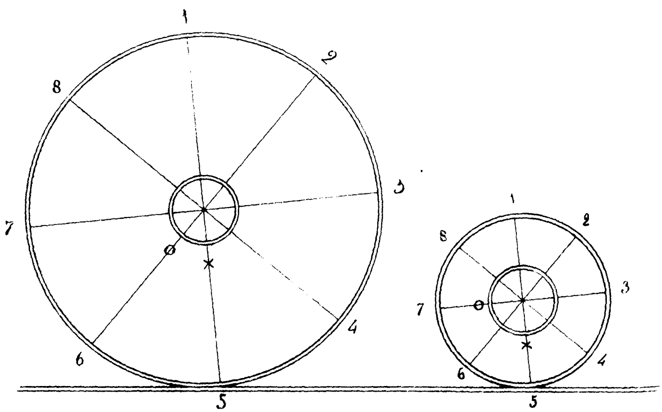


Fig. 3.

over the same sized obstacle, even from a state of rest, we must be blind to conviction not to acknowledge their great superiority, when acted on by the full impulse of the united active inertia of their burden and themselves.

There is, as before stated, a subject very closely connected with, and constantly affecting the subject of inertia last in part discussed, viz. friction, to lessen which in carriage wheels has been the object of research of hundreds of ingenious mechanics; but the immense strength here required to meet the tremendous shocks a carriage has to undergo, has prevented the adoption of many ingenious contrivances, which otherwise might have been useful. Friction is a very excessive drawback to the active inertia, and, consequently, draught of a carriage; it is a natural result of weight, and always bears a certain proportion to it, and therefore the greater the weight the greater the friction. This friction tends most eminently to lessen the force of this inertia, and that in proportion to the roughness of the parts in contact, and likewise in proportion to the length of the space of that roughness.

That is, a body, say a sledge for instance, having to pass over a surface with a given force, must naturally be gradually retarded, until the friction becomes superior to the momentum of that body, and therefore induces it to a state of rest. Suppose a body, A (Plate 3, Fig. 1), has to pass or slide over a surface, B, by the impulse of a given force, say twenty pounds, that force must be uniformly retarded until it gain a state of rest, which we will suppose to take place at C, when, if we wish it to pass on the same distance further, it will require the same impulse, or twenty pounds, as it had at A, to effect it. The shorter, therefore, this retarding surface is, say half, as Fig. 2, at the end of which it is to receive a new impulse, the less exertion of power will be required to continue its motion. Now it must appear, that as the velocity of A,

at its setting out is 20, and coming to a state of rest at C, its medium force at B would be 10, and therefore if it is to receive a new impulse at half the distance, 10 only would be required to keep up its velocity.

The action of axletrees within their boxes is precisely on this principle, the box only forming the road to the sliding arm.

Now as friction increases in proportion to weight and roughness of surfaces, and inertia a constantly retarding force from this friction, and therefore the velocity greater in proportion as the space to run over is less: the more we can reduce the space forming the resistance, the less extrinsic power will the moving body require to continue its motion. I trust this is a theorem that will be admitted.

It is on this principle that high wheels may be traced to point out the most eminent advantages, inasmuch as they form the only remedy to excess of friction from excess of weight; and indeed it is a peculiar property of the wheel by which we can keep lessening the friction, just in proportion as the weight engenders it.

The high wheel then, certainly forms the means of shortening our road of friction within the box, and therefore reduces the quantity of that friction in proportion to its height, by which the inertia is rendered effective, and less power required. I shall now endeavour to make this clear by the following diagram.

Fig. 3 represents two wheels, one as high again as the other, having the same sized box in each, which must be the case, as they are supposed to take an axletree of sufficient strength to carry a given weight. They have each eight intersections through the centre, which enables us to ascertain the proportion the circle of the box bears to the rim of each. We may thence perceive that the space in the rim of the larger wheel contained between 5 and 6 is just the same as that of the smaller one contained between 5 and 7, and tracing these sec-

Plate. 4.

Fig. 1.

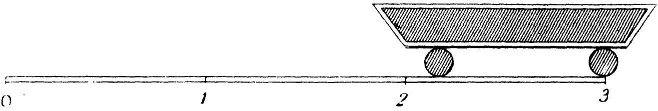
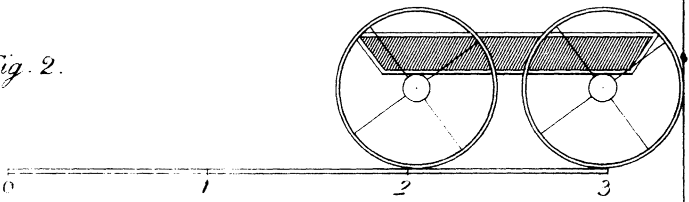


Fig. 2.



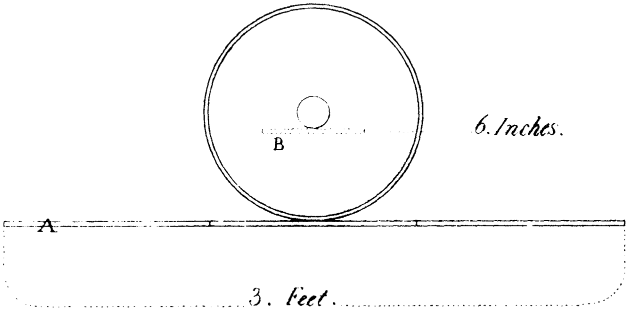


Fig. 3.

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tions to their boxes, we find that the space in the circle of the box of the large wheel (which is in fact the road to the arms of the axle) contained between O and X, is only half the distance of the length of the box in the small wheel that is contained between the corresponding marks, which is the space in which the arm will have to travel in the box of the small one before its rim will have measured the same distance on the ground as the large one, and which space in the box is just double that which the arm will have to travel in the box of the large wheel before the rim will have measured the same distance on the ground as the large one.

We may illustrate this further, by supposing a carriage without wheels, and the arms of the axles to slide over a surface as smooth as a box, like a sledge, suppose the length of the space to be three feet, Plate 4, Fig. 1. If this carriage were drawn from 3 to 0, it would have three feet of friction; but if it be placed on wheels of three feet diameter, as suppose Fig. 2. to be, it would go from 3 to 0 in one revolution of the wheels, because their circumference would just measure that distance. Now supposing the arm and box to be two inches in diameter, that would give six inches circumference for the box, which is now the road for the axle's arm; and as this box makes the same revolution with the rim of the wheel, it therefore goes round only once, forming a space of only six inches for the arms to rub or slide over, while the carriage and wheels have passed through a space of three feet, so that suppose the outside circle of this wheel, Fig. 3, to be turned into a straight line, and the circumference of the box also, one would bear a proportion of six inches to three feet, as the lines A and B, Fig. 3. Now, an impulse given to the whole burden, sufficient to move it six inches only on the three feet surface, would, by the application of this wheel, be sufficient to cause the whole machine to

pass through three feet; while, without the wheel, the same strength would be required every six inches, and consequently take six times the labour to get through the said space of three feet, so that velocity is increased and friction lessened in proportion to the excess which the circumference of the wheel bears to that of its box; and the effect of the lever in overcoming friction in the cohesion of substances may be thus explained:—Suppose the circle A, Plate 5, Fig. 1, to represent an axle-tree arm, and the circle or ring round it to represent the box fastened so very tight as not to be moved upon the arm by the lever B; but if an additional length, as C, be added, it must give double the power. From these observations it must follow, that the less resistance there is to the momentum of a moving body, the greater will be its force, and therefore the less extrinsic power it will require to continue its motion, which in this case is the original source of that motion.

But here, it will justly be remarked, a loss of time in this instance follows the gain of power; and therefore it will be asked, where is the advantage. But here we are supposing for a moment only that the centre is a stationary body, and the lever revolving round it; and whenever this is the case, as in all mill and clock-work, this must invariably be the consequence. But with a carriage, as regarding the velocity of its passing motion, it is very different, and, what is most extraordinary, the contrary is the result, from the centre being not a revolving stationary body, but a passing unrevolving one; not that the wheel itself makes more revolutions in the same space. On the contrary, as far as regards that alone, it obeys the above law of mechanics, and from hence the advantage is derived. But that, as far as regards its passing motion, together with the whole body, it is infinitely superior, because the great cause that retards our machine, viz. friction, is so much lessened, as before explained, leaving the active inertia to act with so much force; for we are assured, that if a body, once put

Fig. 1. *Plate 5.*

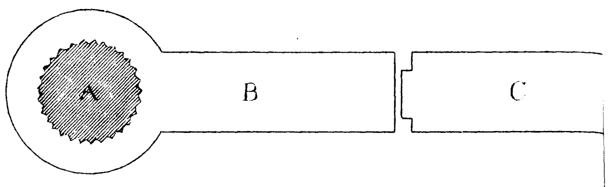


Fig. 2.

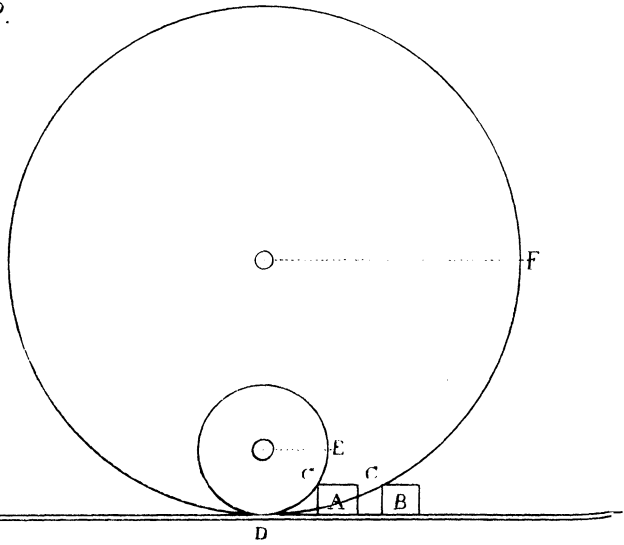
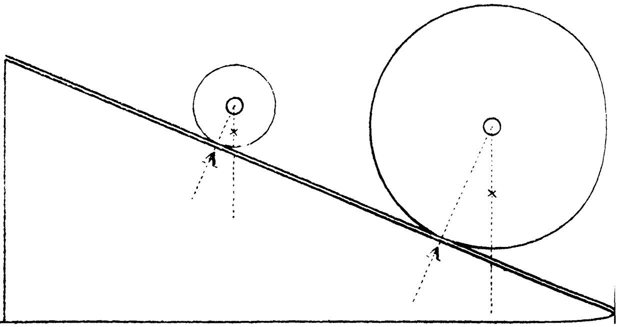


Fig. 3.



in motion, received no resistance from friction, air, &c. it would continue to move on for ever. If I were asked how this principle affected the horse drawing a carriage, I should briefly answer, that suppose a horse drawing a heavy burden with a small wheel, is obliged to renew the impulse to the vehicle a thousand times in a distance of two miles, by the application of a wheel as high again, he would have occasion to exert only 500 impulses of the same force; thus his strength of course would not be half so exhausted, by which he would be enabled to keep up his pace a greater length of time, without injury, and if we carry on this principle, we may therefore conclude, that horses would last the proprietors as long again as they now do.

This I trust will be seen to bear a just analogy to the upper example; to be added to these observations, are those circumstances of the oil clogging and losing its efficacy from the heat of friction, and the consequent wear of both box and arm.

The superiority of high wheels, as far at least as regards the friction in their centre, I submit is evident, and appears to me incontrovertible.

Having, I trust, put the subject of friction in a light which I hope is clear, I shall make a few more particular observations on the state of the roads, as bearing much upon the whole subject; indeed the several points hinted at, so mutually bear upon each other, that they cannot be wholly separated.

Roads in general, may be divided into level and hilly, soft and hard, and with respect to a carriage travelling, these several states are continually varying, and presenting themselves, which, together with the time of the year, affecting continually both the cattle and the carriage they draw, prevent coachmen generally from forming any accurate judgment upon the following of the vehicle which they drive. On a level hard road, friction is the only obstacle (if we reject the trifling resistance of the air) which presents itself, to be overcome. Level roads being the best situa-

tion for carriages to run upon, from the draught being so much lessened, should be taken advantage of by all those persons whose vehicles are intended to travel in this situation only, by which they would find their account in the great saving of wear in both horses and carriage, for the same height of wheel what might best facilitate the draught in this situation, will not answer for those carriages which have occasional hills to surmount; but level as well as other roads are constantly liable to the variations of hard and soft, from the extreme changeability of our climate, and as I have before observed, the latter quality is certainly the worst that can be met with, and forms the greatest resistance to the progress of the vehicle. The present manner of rounding the road in the middle, materially contributes to increase the resistance; and the present construction of wheels adds greatly to the whole draught.

These defects reciprocally act upon each other in a way which persons in general are very little acquainted with. With respect to soft roads, I need only remark the resistance they form is always in proportion to the weight of the carriage, the narrowness of the tyre, now so highly and absurdly patronised, and the degree of stiffness of the soil. As far as regards the roads which are rounded in the middle, I may observe, that in consequence of the throwing the carriage out of its perpendicular*, the edges of the tyre instead of the flat of them, act upon the road, and therefore cut a rut much sooner than it otherwise would, rooting up the earth very fast, and burying the rim of the wheel much deeper in the ground during the journey, and excess of draught is the natural result. But they tend also to increase the draught most excessively by their altering the situation of the friction in the wheels, and transferring part of the friction from the small circle of the box to the sides of the naves by the superincumbent weight, thrusting the

* See "Cursory Remarks," pages 20, 21, and 22.

washers of the axles against the inward part of the nave on one side, and the larger surface of the nuts against the outside part of the nave on the other, and when we add to these inconveniences mentioned, the grinding effects of the dished wheel upon the road, we cannot be surprised at the general state of the roads in bad weather.

The relative weight of wheels to their burden and the inclined plane comes next into consideration, in which I shall have occasion to revert again to the effects that the several points hitherto treated of have upon the whole, being so intimately connected with each other, and after having pointed out a method to ascertain the height of wheel for any particular carriage; I shall conclude this short inquiry by some recapitulatory observations, and, from the whole, point out the general advantages.

I before observed, that wheels can never be treated of without reference to their weight, nor abstractedly from their burden, if we intend to deduce any accurate results as to the effect of the whole. For indeed, its the burden they carry that produce all the phenomena relating to them.

The lever-like principle and the manner in which the weight acts within the box of the wheel have been sufficiently explained in the first part of my Cursory Remarks, to need any further observation, except so far as will be necessary to elucidate the other part bearing upon the subject.

The principles laid down in the first part of my Cursory Remarks for carriages descending inclined planes, are perfectly applicable in all situations when the carriage is in motion, for during the time the weight is pulled forward, so as to keep the wheel revolving, that extrinsic force acts completely the same upon the wheels, as the gravity of their burden does in descending the inclined plane, or its inertia or momentum on level road, which it is to be remembered brings out the whole of the lever-like principles, and the advantages of the high wheels. A great part of which, is always lost in their first

moving from a state of rest, in consequence of the obstinate resistance of the passive inertia (as I have taken the liberty to call it) of the body or weight. It is therefore from the whole machine as a moving body, that we derive considerable advantage to the draught.

I feel here inclined to say a few words on the lever-like principles of the wheel, and its action in clayey soft roads, or in gravel and on the level. First I may remark, that the advantage of a large wheel is more strikingly shewn in passing from a state of rest over an obstacle of a given size, than perhaps in any other instance, which we shall find to be almost in proportion to the increase of height; and as soft roads at all times form an obstacle to the wheel, perfectly analogous and as that state of road occurs at least two thirds of the year, if not more, considering the effect of occasional showers on the road, I think their decided advantage will not fail to strike the mind of the candid reader; this will be shewn by the following example. Plate 5, Fig. 3, represents one wheel four times as large, and consequently to be considered four times as heavy as the other; they are to be considered as carrying the same weight, and to pass over the same sized obstacle A. and B. We shall find by experiment, that about one-third only of the power will bring the high wheel over the obstacle, that was necessary to pull the small one over the same. Here I trust the common principle of lever may be perceived, having a fulcrum * formed in each, at C. C. by the obstacle between their two extremes, and whenever wheels sink into soft roads, the road at the fore part always forms an obstacle of this kind, forming a complete fulcrum, and in this situation, high wheels have just the same advantage, and most eminently diminish the draught.

In making experiments on this subject, unless we

* The essential principle constituting the lever.

are very wary, we shall be led into some very serious errors, and therefore we must not too suddenly come to our conclusions. The vis inertia I have been considering of, will greatly have a tendency to mislead us, for instance, we say that a wheel as high again as another, will cause the draught to be as light again: now, if a person tries an experiment to prove this, by a comparison of the wheels with weights over a pully, he will naturally expect that half the weight which was found to balance the burden with the small wheel, will be sufficient to balance the same burden with the large wheel, but he will here be mistaken, and will naturally halt to consider the cause; first he is to recollect that the high wheel is as heavy again, and that is added to the whole weight, which adds an obstinacy to the passive vis inertia, counteracting the full force or power of the double length of lever, and instead of its being half, we shall find it to be 11-16ths of the weight required for the small wheel, and if we were to increase the height to double that of the last two, which would be four times the height and weight of the first, we should find, the weight required will be 9-16ths, and so on; we may keep doubling the height, and the weight required will still be less and less, but not less in the proportion to the length of lever the absolute weight, checking that power; this is entirely owing to the obstinacy of that passive inertia with which all bodies endeavour to keep or hold their state of rest. But when these several bodies are put in motion, it is that the advantage is derived from them fully equal to the power I stated them to have, when I was considering them without reference to their weight; for after they are put in motion there is the same degree of obstinacy in them to persevere in that state likewise: here then the consequence would be, that if the same power was constantly applied to these weighty moving bodies, there must of necessity be then an acceleration, and they would pass over a given space in a time comparatively nothing to that of the first

small wheels, for notwithstanding the excessive weight, and, its unwillingness to be moved when at rest, from the weight occasioned by the successive doubling of its height, yet the balancing power becomes less and less. What a prodigious power then must be acquired, when the weight becomes assimulated into the velocity of another body, and that velocity acting uniformly upon it, in its course. And in this case the acceleration would be great, and so much so that the carriage would at last be impelled along by the wheels, and gradually acquire a speed far exceeding that of the horses; but this can never happen, because the moment (supposing it to be the case) the carriage had attained a degree of speed beyond what the horses could keep pace with, it would have then to drag, or rather force along, until that acceleration abated for want of a succession of impulses, keeping up a corresponding velocity, and from the retarding power of the weight, viz. horses and carriage, they would have to force along. But, the reason we have no such acceleration, that is, an acceleration amounting even to the speed of the horses is, because the weight of the carriage is so superior to that of the wheels, that it causes a friction within the box, greater than is possible for the weight of the wheels to overcome, they being so light to the carriage, as to keep their power constantly subordinate to its weight.

All this refers to level roads only, but some persons would be ready from hence to infer, that I conceive the height of wheels on level roads may be increased to any degree with advantage, for every description of carriage; but that is a mistake, for it is this very weight of the wheel which enables us to ascertain where to limit its height, and which must always bear a certain proportion to the weight of the vehicle to which it is attached: for instance, I will suppose a cart toy weighing only a few ounces, that a mouse may be supposed capable of drawing. I should hope no one could be so absurd as to conclude

from what has preceded, that I would recommend 4 wheels of 5 feet in height, which would weigh $3\frac{1}{2}$ cwt., as a means of facilitating the draught to this little animal, and further, that 4 wheels, each 10 feet high, would still be more advantageous? No, the reason of this extravagant supposition is indeed obvious, viz. because the passive vis inertia of such wheels would far exceed the power of the mouse to bring into action, and their relative weight far exceed the absolute weight of the burden, that is the toy, the burden being that which we wish to move, to which also there must be some proportion of power. So that it appears there is a certain proportion, that the weight and height of the wheels must bear to that of the burden and power, to enable that power to become efficient, and to enable them to overcome the friction in their centres, increasing with that burden or superincumbered weight. So that in fact, the very wheels that are best adapted to a loaded cart, would not be the best calculated to facilitate it when *unloaded*. And again, that wheel which is best calculated to facilitate a loaded cart, or a cart loaded to a certain weight, which one horse is capable of drawing, would not be the best for the same load if two horses are intended to be used, because the one horse would not be enabled to bring the active inertia of the wheel and burden into action, but two would give a greater activity to the whole, and as the large wheel is more calculated to give facility when in action, its adoption would occasion infinitely less fatigue to the horses, so that they would be enabled to continue their journey a greater length of time. Where strength is required, incalculable advantage is to be derived from these high wheels, for when once got into action, the horses would have comparatively little to do, for the wheels would do the greater part of the work. I must here again remark, that these observations apply to carriages and wheels on level roads only. And it is necessary to state, that they may be taken advantage of

to the full extent on this local situation, to the great benefit of many hundred individuals; but these local advantages will, I greatly fear, be still overlooked and disregarded: however, there will come a time when every advantage that mechanism holds out, will be laid hold of, and applied to useful purposes, in such situations where the advantage is obvious.

When I come to consider the applications of wheels to carriages for general purposes, it leads us to somewhat different conclusions, for such carriages have various sorts of road to encounter, and the hilly one occasions the greatest draught; but, nevertheless, it is this situation that points out some very curious and important phenomena, and from whence we may deduce very singular and accurate results. The inclined plane then considered, in reference to wheels, enables us to solve many of the difficulties which have hitherto attended the general attempts at elucidation, and by the use of which, the height best adapted for the several sorts of carriages in use, when they are intended for general purposes, is readily ascertained.

I have before observed, that wheels are pulled up an inclined plane by the carriage, as though it was descending a hill of the like declivity; and whether the carriage be placed on high or low props, the relative weight of that carriage considered, independently of the wheels, or the power to keep it in equilibrio, is exactly the same. And, therefore, that is not true which has been asserted by some persons, viz. That high wheels, in consequence of their carrying their burden, when ascending an inclined plane, so much more over their fulcrums than small ones, increase their weight in the same proportion. If this were the fact, it would most unequivocally condemn their use, and overturn that established principle of the inclined plane, which, I believe, was the result of the researches of the laborious Kepler, and which has been received and confirmed by every succeeding inquirer:—viz. "That the power required to keep bodies in equi-

librio, on inclined planes, is to their weight as the perpendicular height of such inclined plane is to its length." Now, the application of high wheels to carriages, does not alter the angle of the plane on which they run; and, therefore, cannot have the effect stated. This view of the case, accurate experiments fully justify.

To make this more clearly understood, see fig. 3, pl. 5, the centre of the high wheel, it may be perceived, being three times as high as that of the small one, which causes the perpendicular line of gravity x to fall three times farther from its fulcrum A. It has therefore been asserted, that the relative weight, in the direction of the dotted line, is so much increased. I shall only say, this is founded in gross error: for, supposing the high wheel to be no heavier than the other, the balancer power is the same.

It is a most singular fact that, although we double the height of the wheel of a carriage of great burden on the inclined plane, by which it becomes double the weight, forming all that excess of weight additional to the said carriage; but, by which we are enabled to ascertain, the maximum of height the carriage will bear, still the same power will certainly keep it in equilibrio; (that is, provided it be kept within the limits hereinafter prescribed), if not preponderate. So that this proves distinctly a superior mechanical advantage of the high wheel, to say nothing about the loss of the principle of the active inertia in this situation, or the advantage of them in soft roads, or their superiority as to friction, explained in a former page.

That active inertia which acts of itself upon the wheels on level ground is, in ascending steep hills, almost done away, and the horses are obliged to make up for its absence, by a greater exertion of their muscular strength. But, it is their taking part of the absolute weight of the carriage, the consequence of this situation, in addition to the above, which occasions the draught to be so excessive; and which it is, together with the situation being highly

disadvantageous to the exertion of their own physical strength, where most is required, that causes them to be so much distressed: the brutal disregard which we at times observe to this situation of the poor animals, is as disgusting as it is inhuman.

In proceeding to my observation on the relative weight of wheels to their burden, &c. &c. I beg to observe, that the burden is the grand mover and immediate source of action to the wheels, and from whence all their phenomena result; and, in proportion as that is greater, so in proportion does the weight of the wheels become of less consequence. The power must likewise always bear some proportion to that burden; and if we know the limit of our power, which is absolutely necessary, then we must proportion our burden so as to come within its effect: the force of this observation will shortly appear.

In order to do this, it will first be necessary to consider or ascertain the weight of the carriage and burdens, which the wheels are intended to carry or sustain.

Next to this, the power which we intend to employ, and the greatest declivity this weight is to be drawn up by this same power.

These are the first inquiries to be made, and are essential, as I think will be obvious, in order to adapt a wheel that shall give the greatest facility to the draught. I shall now endeavour to prove the necessity of these inquiries, by shewing the indefeasible connexion the wheel and carriage has with them.

One of the most prominent, and indeed, essential features in this inquiry, is the Inclined Plane, which is so interwoven with this subject, that we cannot proceed or come to any correct conclusion without it. The weight of a wheel, be it what it may, arising from the increase of its height, takes away but a small portion of the power gained by such increase; that is, when on level road, and sustaining a burden in its centre, provided it be drawn from

Plate. 6.

Fig. 1.

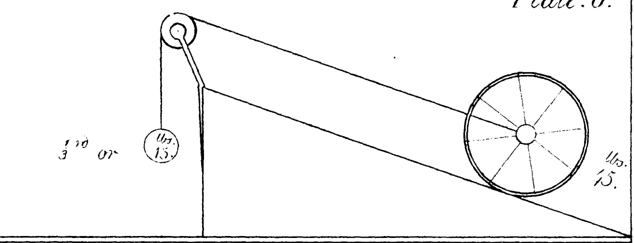


Fig. 2.

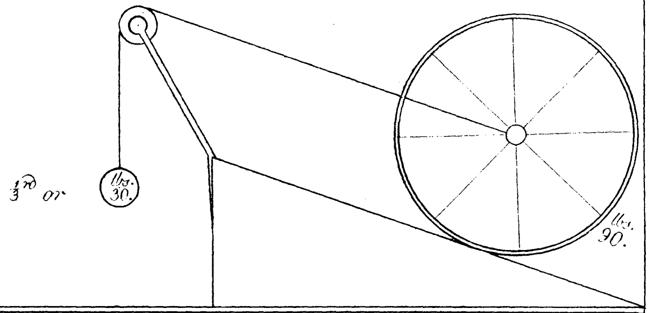


Fig. 3.

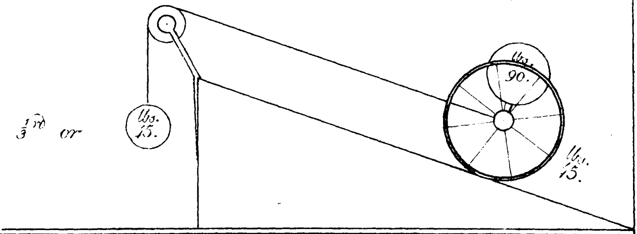
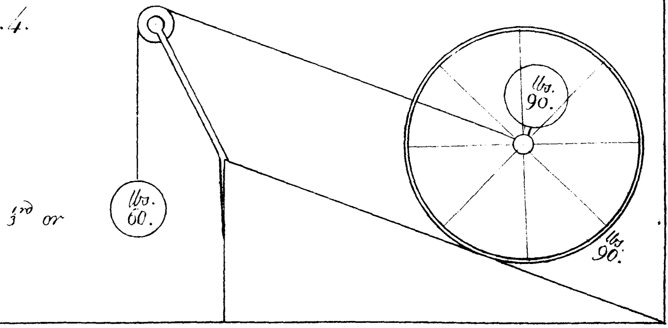


Fig. 4.



P. Archer Sculpt.

that centre, but the moment we begin to draw it up the most slightly inclined plane, a portion of its absolute weight acts against us, and that in proportion to the inclination of that plane. The power required, as before observed, to draw bodies up inclined planes, or to keep them in equilibrio, is to their weight, (that is, exclusive of friction), as the perpendicular height of such inclined plane is to its length. This well known and accurate theorem, which is the basis of our inquiry, being premised, I shall proceed to an example.

Suppose an angle of 19½ degrees, which gives an inclined plane, whose perpendicular height is just one-third of its length. Now this being the case, it follows, that all bodies, and consequently wheels placed on this plane require one-third of their absolute weight to draw them up. It follows therefore, that a wheel for instance, weighing 45lbs. placed on this plane, would require just 15lbs. See Plate 6, Fig. 1.

And one double its height, and consequently twice the weight, or 90lbs. would require 30lbs. See Fig. 2.

Now supposing the small wheel, Fig. 3, weighing 45lbs. to carry a burden of 90lbs. and allowing one-third agreeably to the principle before named, to pull it up, it would give just 45lbs. or the third of the whole. But here, by the application of burden, we must recollect we have a new resistance to overcome, viz. the friction in the box, which at present I shall consider out of the question.

This 45lbs. we must here suppose to be the maximum of the power, and is the quantity necessary independently of the friction to purchase the whole.

Now, admitting for a moment, the advantage of high wheels on level roads to have been fully proved, we should be induced to think, that a wheel twice the height of the one here employed would, as on level road, ease our draught in proportion. However

now we begin to discover our error, for we should expect that the 45lbs. found necessary in the last example, would be considerably more than required, when we had substituted this high wheel.

But we are to recollect that when we increase the height of a wheel, we at the same time increase its weight in proportion, consequently when we double the height of the wheel weighing 45lbs. we increase the weight 45lbs. making the weight of it 90lbs.

Now supposing we have substituted this large wheel, Fig. 4. weighing 90lbs. for that weighing 45lbs. to the carriage with the burden of 90lbs. on the inclined plane of 19½ degrees, and admitting the foregoing theorem, we should find that one-third of the whole weight, which is now, 180 lbs.

Wheels	90
Burden	90
	180

would be required, making 60lbs. instead, as in the last experiment, of 45lbs. being an addition of 15lbs. So that supposing 45lbs. to be the maximum of the power, or horse's strength, he must on this hill stick fast.

The reason here is very obvious, the wheel alone being 90lbs. requires 30lbs. in this situation, whereas the small ones required only 15lbs.; the weight required for the burden is in both cases the same. So that the additional weight arises solely from the increased size of the wheel, which has so increased the draught, as to render the power totally inadequate to draw the whole up the hill. Whereas on level road the increase of height in the wheel, instead of requiring a greater power than the small wheel, which on the level road, instead of 45lbs. would only require about 1-60th or 3lbs.; one-third less than this at least, would be found adequate, therefore 2lbs. only would answer.

Here we may observe what a wonderful difference arises in the draught in these two situations, viz. the level road and hill. Therefore we need not be surprised at the extra exertion of an animal when in this latter situation; but I may also remark, that this inclined plane of $19\frac{1}{2}$ is nearly four times greater than any hill that horses have to surmount, as Highgate Hill for instance, is only at its steepest part $5\frac{1}{2}$ degrees elevation, which gives a perpendicular height of about 1-10th of its length. Now, if therefore, this carriage we have been speaking of, were placed on a plane of this same elevation as Highgate Hill, we must take 1-10th of the burden of 180, which would give us instead of 45lbs. only 18lbs.

We will now suppose for a further illustration, that this carriage or burden of 90lbs. is to be drawn up a hill of $5\frac{1}{2}$ inclination, as that at Highgate, and admit that our power as before is equal to 45lbs. We will suppose this to be a horse, which has to draw this burden many miles, and only one hill of this angle to encounter, the other part being level road, thus:————^———— now knowing that the higher the wheel is, the more on level road the draught will be facilitated. We want to ascertain to what height we may carry our wheels, that their absolute weight on this hill of $5\frac{1}{2}$ degrees, when added to that of the power may not exceed the power of our horse, which we have supposed to be 45lbs. We now try the small wheel Fig. 1. weighing 45lbs. our burden we are to recollect is 90 90

$$\begin{array}{r} 90 \\ 45 \\ \hline 135 \\ \hline \end{array}$$

Gives 135lbs. the whole weight.

The relative weight on any hill being as before observed, as the perpendicular height is to its

length, and the perpendicular of this being 1-10th, we are to divide 135 by 10 . . 10)135

$13\frac{5}{10}$

so that we perceive here is only $13\frac{5}{10}$, and our power is capable of 45lbs. consequently we may increase the height: let us try one as high again, weighing 90lbs. now this added to the burden of 90 + 90 = 180, this being divided by 1-10th as the last, gives . . . . . 10)180

18

We perceive 18lbs. while our power is 45lbs. so we may still increase; suppose we double again the height of the last wheel, weighing 90lbs. it will give us a wheel weighing 180lbs. which added to the burden of 90. . . 180 wheels.
90 burden.

270

gives 270 for the whole; this being divided by the perpendicular height of the hill as before, viz. - . . . . $\frac{1}{10}$)270

27

gives 27, so that we may still increase; let us double again 270 and 270 = 540 for the weight of wheel, which, added to the original burden of 90, gives
540 wheels.
90 burden.

630

gives 630; this divided by 10)630

63

gives us 63, while our power is only equal to 45, so that we are now too high, and although our power would have little or no force to exert on the level with this wheel yet when he came to the hill, all his power would be ineffectual.

Now in the latter case the friction consequent on the application of burden to wheels was entirely omitted, and in the case of applying burden to wheels, as in a real carriage, we find we have this additional resistance, viz. friction, to overcome, caused by the rubbing of the arm of the axle within the box; so that by this circumstance a greater power will be required than that stated in the theorem. This increase of resistance or friction is proportioned, as was before observed, to the superincumbent weight, and the roughness of the surface, and from the consideration of this friction and the weight of the wheel and burden, in connexion with their effects on the inclined plane, we are enabled pretty accurately to ascertain the maximum height of wheel, that will best facilitate the draught.

It is very easy to discover, from the explanation of friction in a foregoing page, why wheels facilitate the draught. We shall plainly perceive also that there must be a certain maximum of height, if we consider what has been there observed, together with the following remarks.

Suppose a burden of any weight, to be drawn up an inclined plane, and the axletree arms to slide up without wheels, the friction will of course be the greatest, as the axletrees will have to pass over the longest space, see page 16. Pl. 4. Fig. 1. Then suppose we put wheels of the smallest possible diameter on first, which will be a mere ring round the arms, gradually increasing their size. We shall find that every increase of size will on the principle there explained lessen the space of friction, and less power will be required. But we can easily perceive, as this increase of size in the wheels, causes an increase of weight, that they may

be carried so high, that when on an inclined plane their relative weight will far exceed the resistance of the friction of the arms without wheels and the absolute weight of the whole burden, and therefore render the whole too great for the power, calculated to purchase up this hill. So by this we shall find their weight would become a greater drawback to the draught than the friction of the arms of the axle was without wheels. We may now perceive therefore, that the great object of wheels lies in overcoming this friction, or at least lessening it as much as possible.

In order to make this clear, suppose a burden, without wheels, of 400lbs. is to be drawn up an inclined plane, whose perpendicular height is just one-third of its length. Now if there were no friction one-third of 400lbs. or 133⅓lbs. would be sufficient to balance it, but we shall find a considerable deal more required, and whatever is the excess, that excess is the amount of the friction. Now if in employing wheels to overcome this resistance, we increase their size so much, that their relative weight, added to the burden, requires more power than that without wheels, or if even the same, what advantage have we gained? certainly none in the situation of the inclined plane, though a great one on level road, but as we have these inclined planes frequently to surmount, we cannot overlook them in the consideration of this subject.

These observations have been drawn from a series of pretty accurate experiments, which have uniformly produced a result confirmatory and clear. I shall submit one from which the principle will be obvious. The inclined plane on which I made this experiment, was an angle of five degrees, the perpendicular height of which to its length is as $\frac{12}{128}$ or $\frac{4}{45}$ or thereabouts. The carriage and burden together weighed 36lbs.; the boxes or naves were so constructed as to admit of wheels of different sizes being placed on them, so that I had no oc-

casion to shift them from the arms, and the friction therefore was in every case alike. I first tried a very small set of wheels, the whole weighing only 24oz. which is about $\frac{1}{23}$ of the burden. I found by the before-mentioned theorem, that the relative weight of the burden and wheels on this particular inclination of plane was about 3lbs. 5oz. $\frac{10}{45}$, which ought to have held the whole in equilibrio, but it required 3lbs. 15oz. to gently draw it up the hill or plane; here we perceive 10oz. of resistance above the relative weight, which is just so much friction, and is above one-sixth of the whole relative weight. I now tried a set of wheels on the same naves twice the height and double the weight, and about $\frac{1}{12}$th of the burden, which gave an increase in the relative weight of 2oz. $\frac{20}{45}$, being 3lbs. 7oz. $\frac{20}{45}$. But, although this wheel was twice as heavy as the former one, yet it now required only 3lbs. 13oz. to draw it up the plane; by which we have only 5½oz. of friction. The friction being the difference between the relative weight of the whole machine, and that which is actually required to draw it up the plane. Now, although there is 4½oz. of friction lost between this and the last experiment, there is only 2oz. gained to the power in this situation, because the increased weight of the wheel takes from the advantage, but on level road it is the whole gain. I now tried a set of wheels to the same carriage, twice the height of the last, and of course double the weight, or 98oz. or about $\frac{1}{6}$ of the weight of the burden. I found the relative weight now agreeable to the theorem, 3lbs. 11oz. $\frac{39}{45}$, yet although there was this increase of weight, the actual power required to draw the whole up the plane was only 3lbs. 13oz., the same as in the last; here we perceive there is but a trifle more than 1oz. friction. Although the advantage gained to the power is but 2oz.; this advantage, though small, is a decided proof that the weight of the wheels when kept within a certain extent even in this worst situation,

viz. the inclined plane, is no material drawback. And it is to be recollected that as these several powers acted upon the carriage from a state of rest, the passive vis inertia before spoken of was highly unfavourable, for even on a hill after the first impulse is given, I conceive the active inertia is not wholly destroyed, and the less inclination the hill is of, the more this inertia assists the power.

I shall now apply the principle of this experiment to the stage coach, and endeavour to prove by analogy that the present practice of putting low wheels to these vehicles, however prejudice may sanction it, is detrimental to the draught, and contrary to theory and accurate experiment. And then endeavour to give a general rule for the wheeling of carriages of any description, or weight, derived from the foregoing considerations, and conclude with a few recapitulatory observations.

A stage coach when loaded, weighs sometimes 3 tons; if we deduct the weight of the four wheels, which is about 400lbs. it will leave 2 tons, 16 cwt. 1 qr. 20 lbs. for the burden they have to carry, and the proportion they bear to the burden is about $\frac{1}{15}$ of it. We found, in the experiment just mentioned, that wheels $\frac{1}{12}$ of the burden's weight, when tried on the inclined plane, occasion considerably less draught than those of $\frac{1}{24}$, being as high again as the latter. We found also, that when we tried those of $\frac{1}{6}$ of the burden, being as high again as those of $\frac{1}{12}$, on the same inclined plane, that the draught was not increased. Therefore, it appears, that wheels may be carried to any height with advantage, even for hilly roads, so long as their aggregate weight does not exceed one-sixth of the weight of the burden they have to carry. It is extremely clear from this, that as the wheels of stages are no more than $\frac{1}{15}$ of the whole weight, they are infinitely too low for the advantage of the proprietor. And it will be found that they might actually be carried as high again, before their weight would add to the draught

even on this worst of situations, the inclined plane, and where alone their weight can possibly act with any disadvantage; while the advantage of their height on level road becomes incalculably great, from the aptitude of wheels to roll, and from their facilitating the active inertia, so powerful an agent in assisting the draught. Having, I trust, pointed out the relation that exists between the inclined plane, burden, power, &c. I think from the experiments I have made, that I may venture to give what was just now stated as a general rule for the height of wheels, viz. that they may be made at all times as high as possible, keeping a proper strength in view, so that that height does not occasion a weight in proportion to the burden they carry, of more than 1-6th or thereabouts. So that we perceive the burden must always be considered in reference to the power employed, and the weight of the wheels subordinate, and in reference to both. And this will be most strikingly seen, if we again, suppose, to a cart toy (that a mouse is just capable of drawing up an inclined plane) the application of very high wheels, the gravity of such wheels would of course drag mouse and cart backwards; this simple, though extravagant idea, at once shews there is a specific relation which the weight of wheels must bear to their burden and power, and which is about what I have stated.

I have given this as a general rule, and from which the proper height of wheels necessary for any carriage is to be deduced. In order to make this more clear, observe:

The absolute weight of the burden must be ascertained; whatever that may be, we know that it will admit a wheel about $\frac{1}{6}$th of that weight, provided that weight be derived from the greatest possible height the strength of our wheel will admit us to go to; then, as we know that wheels increase in weight nearly in the proportion to their

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height, we can easily find out what height our vehicle will bear. For instance, if a wheel of three feet diameter give 80lbs., one of six feet will give 160lbs., this will vary a little more or less as we either increase or diminish the strength. And we shall easily perceive by this method whether the height of the wheel we think of putting to our machine, yields a weight exceeding the proportion it ought to bear.

Here we perceive is a precise method to ascertain with tolerable accuracy the height of wheels best calculated to ease the draught of any carriage, but I beg it may be understood that my object in this brief inquiry has been more to ascertain the principles upon which this subject rests, than any thing else; for the height of wheels must at all times be in part governed by necessary convenience, according to the various uses of the carriage.

In these elucidations, I have rather extravagantly considered the subject, for the purpose of placing it in the clearest point of view, for we shall never find that carriages ever will admit of their present height of wheels being doubled, much more trebled, &c.

But I am clearly of opinion that the present system of low wheeling of carriages, is most seriously destructive of the cattle, and that stage-masters in particular are great sufferers from this circumstance, and are the dupes of prejudiced opinion and hypothetical uncertainty. But if, instead of listening to such vague information, they were to endeavour to convince themselves by actual experiment, having some principle to go by, they would come to conclusions in which they would very soon find their account.

Before I quit this part of the subject, I cannot help observing that the contemplation of the inclined plane, has I trust, as I have humbly shewn, enabled me to ascertain with some degree of accuracy the principal relation and property of the

carriage wheel, which hitherto, I believe, it will be acknowledged, has been very much misunderstood, and depending upon vague hypothesis.

There has occurred another, perhaps important, at least useful result from this inquiry, and which I consider as a mere spark, that, however, may at no distant period, be kindled by more able heads into a flame of knowledge on the subject of friction, that will greatly enlighten the science of mechanics. For by the use of the inclined plane, it appears we are enabled to point out most accurately the quantity of friction in the axles and boxes, as it exists totally distinct from the relative weight of the carriage.

The relative weight of the carriage, and consequently its wheels, is, as I have shewn, as the perpendicular height of the inclined plane is to its length. In the experiment, we shall find that more weight is always required than exactly corresponds with this rule. The exact excess is the precise measure or quantity of friction which we shall likewise find increases more and more with the increase of the superincumbent weight, and as the frictional parts are rougher and less lubricated with oil. So that by a new series of experiments we may ascertain to the greatest nicety, the quantity of friction on any given increase of weight.

From the view I have been enabled to take of this subject, I conceive that there are many advantages to be derived from the use of high wheels to several classes of persons which have hitherto been totally overlooked. For instance, all those stage-masters, at least, whose wheels run on level road, may derive a great saving in the wear of their cattle in particular, and also of their carriages, by the use of wheels as high as other conveniences will possibly admit, as the weight of high wheels when in motion, on level road particularly, is not the smallest drawback to the draught, while their height wonderfully facilitates it.

The present absurd practice of low wheeling carriages may be clearly traced as a matter of necessity, arising from an equally absurd and false notion of short carriages facilitating the draught, which favourite idea having caused carriages to be very much elevated above the ground, while, at the same time, it has reduced the space of their base, if I may so say, together with the practice of high heavy loading, has been the parent of much mischief in the repeated loss of valuable life and limb.

But although I have stated high wheels would be highly advantageous to stage-masters, whose wheels run on level road; I may say, they will not be of less profit to others by adopting them as high as possible to those carriages which travel hilly roads also. Since it appears that a stage, weighing three tons, would admit of wheels nearly as high again as those now in use, without their weight, when the carriage is placed on the hill, adding to the draught,* while, until they attained that height, they would be found to facilitate its progress with infinitely less exertion to the horses.

Another class of persons are carriers, to whom the adoption of high wheels to their vehicles would be most universally beneficial; and if they substituted upright wheels in lieu of dished ones, they, as well as all other persons, would find their account in it.

I should here feel inclined to renew the subject of conical or dished and broad wheels, but it has been so repeatedly taken up to no avail, that I conceive all that I could add to my former observations, would be quite useless;† but I cannot help stating, that I think it is nothing but the blindest infatuation that keeps them in general use, at least, to vehicles of all descriptions; to those for town, as well as to

* From this circumstance we may infer, what great advantage would be derived from broad wheels for soft roads; this destroying the argument urged against their weight.

† See Cursory Remarks, pages 16, 17, 18, and 21.

those for country use only. The only real advantage that is derived from dished wheels being the prevention of contact in very crowded situations, where there is a numerous collection of carriages, and the coachmen cutting and striving for the lead. Why, therefore, they should be adopted for cart, waggon, truck, &c. both for general and local situations, when they are so detrimental to the draught, I must leave for the respective proprietors of each to determine. But of all the absurdities that meet the public eye, that of the excessively dished wheels of 18 inches tyre, used to waggons of 10 tons burden, is perhaps the greatest, and most unaccountable, and which, while it occasions an extra draught of at least two horses, loosens rather than improves the road.

I shall now offer a few brief observations recapitulatory of the foregoing remarks. It appears to me in every light that I have been enabled to view the mechanical construction and application of the wheel, that, in the first place, the higher they are, the more easily they will travel over uneven surfaces, and from which, less tremor is conveyed both to themselves and the carriage they sustain; the natural result of which is less noise to the passengers, less wear of the carriage, as well also of the wheels themselves. They most eminently facilitate the draught in the reduction of the immense quantity of friction always experienced, by which, that powerful agent inertia, is rendered so effective in assisting the efforts of the horses, while the natural consequence of this reduction of friction is, their not being so liable to fire by quick travelling, and not requiring to be greased so often on the road.

The clear inference from these remarks is a saving of immense expense in the wear of our cattle, and every part of the machine, which will most satisfactorily evince itself to every proprietor, if he chooses to put the experiment in practice.

I am induced to think that the practice of trying

the relative draught of carriages by a weight over a pulley; and that, from a state of rest, without taking into consideration, the effects of the two states, (as I have presumed to divide them,) of inertia, and a due regard to weight, and its effect on the inclined plane, has constantly led to false conclusions.

I cannot but view the wheel as attached to a carriage as a lever, by which we gain very great power without loss of time, and therefore forms an exception to the general principle hitherto laid down in the science of mechanics.

Thus having attempted to draw out this subject from the mist in which it appears to have been surrounded, I trust I have not wholly failed; and however it may be appreciated or attacked, I have every reason to believe the principle will be found to stand the test of accurate experiment, and therefore correct, and which, if properly considered and applied, will prove very useful.

Before I close these remarks, I cannot help observing, that it is with deep concern I view the continual accidents and loss of life from the present structure of stages, these effects are clearly to be traced to high loading and short carriages,* the latter having given rise to the low wheeled system, so very injurious to the draught; but the prejudice is such in favour of this system, that the present facility of travelling is falsely attributed to it; whereas the real cause arises from a combination of other circumstances, viz. the improvement of the roads, (so far as regards the material used,) the better sort of cattle employed, and the improved construction of the stage itself; I mean so far improved (independently of the wheels, the shortness of the carriage, and the high loading,) as regards its facilitating the draught, they being so contrived as to embody, in a high degree, that principle which I stated to be the great

* See Cursory Remarks, p. 22.

principle of easy draught, viz. the whole weight, with the addition of springs, acting as one condensed mass of matter upon the wheels, the long braces, and all those swinging apparatuses, which cause, or have a tendency to cause, a re-action to the weight, being done away; and from this cause, they follow, even with the present wheels, infinitely lighter than nine-tenths of the private gentlemen's carriages in use. And I have great reason to believe, that Sir John Lade, and those gentlemen who some time since composed the Four-in-hand Whip Club and the rage at that time, for the very pleasing exercise of driving, greatly contributed to those improvements, and to whom the public, therefore, generally are most unquestionably indebted for the present facility of journeying. But, although I appear to have condemned the use of short carriages, I beg it may be understood, that I am an enemy to their adoption, so far only as they cause an infringement upon the height of the wheels, at once injuring, instead of improving the draught, while, at the same time, the body is elevated, and consequently, the whole luggage with it, involving every passenger's life in danger. If that desideratum so long sought after, viz. the placing the luggage in an opposite situation to where it is at present placed, viz. the roof, were established by an act of parliament, and a carriage submitted to that unprejudiced body, who have always the general interest and welfare of the community in view, that could be clearly proved to them would fully answer the proprietor's purpose, (which is an indispensable object) as well as insure the safety of the passengers, I am led to believe, that all those evils and accidents which the public have so long, and so justly complained of, would immediately disappear. And here, I beg leave publicly to assert, that such a carriage, I as a practical man having been initiated from the earliest period of my youth into the upper part of the coach-making business submitted to the Society

of Arts last Session, and which, from some peculiar circumstances, that it would be idle in me to name, being a member of that body, was not approved of. But which, I do most publicly assert, as a practical man, is most eminently calculated to answer the public and the proprietor's purpose, embodying all the advantages of draught and safety, and all of which I should be happy to prove, before the whole trade, and before any body of gentlemen who should think proper to take up, for the public benefit, the consideration of the subject. And until some public spirited individuals do take it up, the community will still lie under the inconveniences that have been so justly, so universally, and so long complained of.

THE END.

BARNARD AND FARLEY,
Skinner-Street, London.

TO THE PUBLIC.

THE fatal and mischievous accidents which are so frequently occurring to stage coaches upon the road, are, I humbly submit, a proof that those too numerous and lamentable instances of a public mischief, call aloud for the nervous arm of parliamentary interference, and which, I am confident, is alone competent to check its extension. Were it only for the purpose of preventing the loss of life, simply considered as to individual safety, humanity, I think, would dictate an inquiry; but when we consider the number of valuable lives daily exposed to risk from those public conveniences, national considerations step in almost to demand that something should be done to ameliorate the danger. The constant, and I might almost say daily, accidents which occur from the overturning of stage coaches, have rendered them so familiar, that they appear to be expected by every post, are received as a matter of course, and consequently excite little or no commiseration, and seem to be considered as an inevitable consequence of riding in a stage. They appear to be associated with the very idea of this vehicle, and a misfortune considered as intrinsically attached to, and indefeasibly connected with it, and therefore the cause ceases to excite inquiry or to effect regard. Although many have been the efforts of philanthropic, mechanical, and enlightened individuals, to ameliorate the dreadful effects, they have from some cause or other failed. And although the proper authority, viz. parliament, has been repeatedly alive to a sense of the mischief, yet some fortuitous circumstances have transpired to prevent any efficient remedy from taking place, notwithstanding their praiseworthy exertions to effect it. What were the nature of those circumstances, I know not, whether the information on the subject has been such as to lead to improper conclusions:

whether it arise from the want of an efficient plan being presented, or whether other pressing matter, considered of more importance, has excluded it from the patient and continued investigation it requires, I am not competent to determine. But I am decidedly of opinion, that no public benefit or amelioration will arise on this subject, unless parliament again seriously take it up, and investigate it to the bottom: if a rigid inquiry takes place, an efficient remedy will, there is not the smallest doubt, be the result of their labours, to the great satisfaction of the public in general, and also to the ultimate pecuniary advantage of the proprietors of stages in particular. However, as the case now stands, I think it has become the duty of all persons, both in and out of the trade of coachmaking, to endeavour to trace this calamitous species of manslaughter (for I can call it nothing else) to its source, and endeavour to devise a remedy. It is my humble opinion, (which I court no man to pin to his sleeve, but to think for himself) that in too many instances the accidents which arise from the glaring defects of the vehicle are most unjustly charged upon the director of its progress, and he individually bears that which alone ought to be attributed to the principle of the vehicle itself. For my own part, I have been a long time truly sensible of the absurdity of its present construction, and, in fact, not only the stages, but carriages in general. But when a prejudiced opinion has been for a long period received and imbibed in the mind of a body of people, it is almost in vain for any individual to attempt to root it out. The facility with which travelling is now performed is, no doubt, of the greatest national utility, and seems to absorb the whole attention of the public, and appears to have sunk all consideration of the fatal consequences which arise out of the system; and is looked upon as a desideratum, before which every other effect must fall, instead of ascertaining whether the former cannot be attained without the latter

following as a consequence. The general erroneous opinion of the cause of the facility with which travelling is accomplished, is, in my mind, one of the causes which prevents the subject from being taken up, and is a false medium, from the general prejudice through which it is viewed. The velocity of travelling is generally and principally attributed to what is termed a great improvement in four-wheeled vehicles, namely, short carriages and low wheels; that is, the bringing of the fore and hind wheels as near together as possible; to effect which, every thing else must yield; and because we almost fly as it were, the coaches are therefore at the utmost pinnacle of improvement, notwithstanding the disastrous effects of almost every journey; and finding fault with their general construction, is considered such a piece of hardihood and presumption as few dare venture upon. Almost the whole credit of the speed is attributed to the short carriages. To effect this, the wheels are reduced in height as much as possible, the hind wheels being brought as near towards the door as allowing room for the passengers to get inside will admit, and the fore one brought so close towards the hinder one, as that, on locking or turning on the perchbolt, not more than half the usual distance allowed by coachmakers, it comes under the very centre of the door-way, which must of necessity be kept very high, in order to prevent the bottom from touching the wheel when turning a corner, to prevent an upset. Now to this erroneous notion, (I say erroneous, because it has repeatedly been proved to be so both by myself and others, particularly by several very accurate and scientific experiments on the large scale in Ireland, by Mr. Edgeworth; for this does not depend upon hypothetical speculations, but is demonstrable by experiment,) I say then again, to this false notion may be traced the whole of the evils which too often appear in the newspapers, while, so far from its being advantageous to the draught, or in any way beneficial to the proprietor,

it is in all points of view just the reverse. If we were to inquire into the real cause of our facility of travelling, we should find it to have arisen from the following circumstances, viz. The improved state of the roads by the constant expensive supply of hard material, and the improved construction of the coaches themselves, (independently of the short-carriage and low wheels,) in acting as one mass or body upon the wheels. The very superior axles and boxes (by which the friction has been greatly reduced) now in use to those formerly employed, and the superior cattle which are almost everywhere adopted. If we take a review of these points, to which alone may be traced the improvement in travelling, and compare them with what they were thirty years ago, we should be led to perceive, that the improvements here have been of that magnitude as justly to claim the credit of the rapidity of journeying, which is so desirable in a commercial kingdom like this. Now, I would ask, if the favourite system of short carriages be the root of all the evils complained of, which may be clearly demonstrated, while no one advantage results, but, on the contrary, pernicious to, all persons and things concerned, both extrinsically and intrinsically in it; whether it does not call for the strong hand of legislative interference to put a period to the mischief, becoming daily more alarming. I will now briefly endeavour to point out the general tendency of this system :—There has for some years existed an idea, that long carriages, or which is the same thing, the hind and fore wheels being far asunder increase the draught, and consequently, the nearer they were brought together, the lighter the carriage will follow! The consequence of this idea (which I need only state, has been repeatedly proved to be false,) has been, that the body has been lifted much higher from the ground than necessary, in order to admit the fore-wheels to lock completely under the centre of the door-way. The luggage boots before

and behind have been curtailed in length, to appear compact, and, as it were, to fit the short carriage; and this defect made up as much as possibility will admit, by giving them greater capacity upwards. The luggage and passenger, both inside and out, being, therefore, elevated with the body, while its base, (if I may so say, that is, the area contained underneath, between the point where the four wheels touch the ground) being lessened, must of necessity render it extremely top-heavy. And when loaden to the shameful height, we frequently see these vehicles, it would require but the most trifling force to pull them over. And when in motion, the least unevenness of road causes them to rock and swag, so as to make one shudder to behold.

It appears then to me, that the erroneous notion, to which I attribute these serious results, originates here. That persons have considered the undoubtedly heavy following and formerly slow progress of stages to the length alone, instead of the heavy and cumbersome manner of building them; to the immense and almost incredible quantity of friction occasioned by the then very inferior axles and boxes; to the badness of the roads, and the inferior sort and slower cattle then used. That all unnecessary length should be avoided, I am willing to allow, because the absolute weight is thereby something lessened; and by bringing the hinder wheels as forward as possible (without sacrificing a proper height) is judicious, and contributes to lessen the draught, by taking, as they are more capable, the greater portion of weight. But the fore wheels being brought as backward as possible, is most absurd and ridiculous, as they are thereby forced deeply into the ground by the superincumbent weight, occasioning an immense increase of draught for the quantity of weight they should sustain, (as I have stated in my Cursory Remarks on Wheel Carriages,) should invariably be in the proportion that the size of them bears to the hinder ones; for, being so much smaller, they go round

the oftener, and the friction of their axles increases in the same proportion. If then it appears no mechanical advantage to the draught, arises from the principle of so short a carriage, but, on the contrary, every disadvantage in this and all other respects, and a dangerous tendency to upset, is alone left for it to boast of. I am induced to think it is almost imperative for the public welfare, that something should be done to expose, and, if possible, explode it, and every means used to elicit a plan of an effective principle. But if so desirable an object be not (for I will not say cannot be) obtained, I would venture professionally to recommend as a remedy (which, by-the-by, would be useless, unless enforced by legislative enactment,) that the body part be kept only a certain height from the ground, whereby the whole weight would be considerably lowered, and a broader base insured, obliging them to have a longer carriage; which, as before observed, will not militate against the draught, but facilitate it, by throwing the fore-wheels forward from the pressure which forces them into the ground. That these carriages being for the purposes of real business, and of such public utility, being the organs of personal and epistolary communication throughout the kingdom, should of all others be as perfect as possible, every one I trust will admit; but so far from the construction being mechanically perfect, it embodies the most glaring defects, which, in the foregoing remarks, I have endeavoured to point out. Now there can be no doubt but that the whole of the mischief arises, as has been repeatedly pointed out, from these carriages being top heavy when loaded, and which is generally attributed to the quantity of luggage on the top of the roof only; whereas it is to that and the general elevation of the whole, causing the former, from its excessive quantity, to have more injurious effects, as also that below it, to which therefore the immediate cause of accident may be traced. But the effect of this weight would most unquestionably be lessened very much

by the remedy just proposed, even provided the dimension of the luggage boots, and that of the luggage on the roof were kept the same; for every one knows that the most trifling weight will cause a preponderation on a body when in a state of equilibrio, and in many instances, if the luggage had been but a few inches lower, it would have prevented an upset when the carriage had been thrown out of its vertical position. But by following this remedy, larger boots would be the consequence; the luggage of the roof therefore might be distributed into lower situations, and the height legally allowed for it on the roof curtailed: so much for the improvements that might be effected with the present plan of arrangement. It appears to me, however, that the thoroughly efficient remedy lies in constructing a carriage so as to admit the luggage, a principal part of the weight being carried below underneath the body, without its being detrimental to draught, or in any way inconvenient to the proprietor, or increasing the actual weight of the vehicle, which is not only possible, but easy and practicable. But, to submit a carriage professing to have such a principle, to a body of men very greatly prejudiced, together with the generality of persons, in favour of the one in use, and who, by adopting it at the uncertainty of its answering their purpose, would subject themselves to heavy expense, is perfectly useless and chimerical; and, in fact, what scarcely any sane man, considering the effect of prejudice and self-interest, would attempt. The trial and adoption, therefore, of any thing differing from the common principle, must be countenanced by a higher authority; must be submitted to men, whose minds, unwarped by any pecuniary, self-interested motives, are therefore open to the light of truth and reason, and from whose high attainments their intellects are not to be imposed upon by fallacious positions, and who therefore, would mark such an attempt, with the degree of disgrace it deserved. The pecuniary, self-interested motives, which I

might say in innumerable instances, we well know are generally to be found under the mask of professed public benefit, and which has been found in many instances to have been the only foundation of an unsubstantial and visionary superstructure, has justly disgusted public men, and prevented them from attending to applications, (with which, by-the-bye, they might at all times be inundated,) and their truly valuable time swallowed up by a torrent of absurd speculations. But, where an evil exists, involving the community at large in its baneful effects, extending even to the loss of life, I trust it will be allowed to call their attention with more urgency, propriety, and justice, than particular circumstances, involving either individual interest, or that of one particular class of his Majesty's subjects. I have been induced to offer, as a practical man, the forgoing observations, in the hope that they may conduce somewhat to the forwarding an improvement in a system which engenders so many distressing occurrences which so frequently appear in the columns of the public prints. And it is most sincerely to be hoped, that the subject will be publicly taken up, fairly investigated, and that practical men, if only from motives of humanity, will assist in endeavouring to establish a system of safe as well as expeditious travelling.

I remain,

With much respect,

The Public's most obedient,

Very humble Servant,

JOHN COOK.

No. 9, Fitzroy Place,
Kentish Town.

BARNARD AND FARLEY,
Skinner Street, London.